MPRS (URBOT) Commercialization

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ABSTRACT

The Man Portable Robotic System (MPRS) project objective was to build and deliver hardened robotic systems to the U.S. Army's 10 Mountain Division in Fort Drum, New York. The system, specifically designed for tunnel and sewer reconnaissance, was equipped with visual and audio sensors that allowed the Army engineers to detect trip wires and booby traps before personnel entered a potentially hostile environment.

The MPRS system has shown to be useful in government and military supported field exercises, but the system has yet to reach the hands of civilian users. Potential users in Law Enforcement and Border Patrol have shown a strong interest in the system, but robotic costs were thought to be prohibitive for law enforcement budgets.

Through the Center for Commercialization of Advanced Technology (CCAT) program[i], an attempt will be made to commercialize the MPRS. This included a detailed market analysis performed to verify the market viability of the technologies. Hence, the first step in this phase is to fully define the marketability of proposed technologies in terms of actual market size, pricing and cost factors, competitive risks and/or advantages, and other key factors used to develop marketing and business plans.

KeyWords: MPRS, URBOT, CCAT, SWAT

1. URBOT PLATFORM AND HISTORY

The MPRS Urban Robot (URBOT) was intended to remove the soldier from the dangerous and labor-intensive process of searching and clearing underground tunnels. The remotely operated URBOT was designed to detect hostile forces, locate and deactivate booby traps, deliver payloads, or simply stop, look, and listen, keeping the soldier safely removed from the hazards below ground. The URBOT is also an effective tool in adversative urban environments that soldiers may find themselves operating in.

Designed to be fully invertible, the system can operate upside down or rightside up with no preference. Since the system was to be operated in the field by real soldiers, it had to be both waterproof and extremely rugged. The URBOT (Figures 1 and 2) is a tracked robot that can be remotely operated with a simple handheld push-button controller. Video is displayed through a five-inch active matrix LCD panel.

The system is equipped with four cameras. A Sony 24X zoom, auto focus, auto iris, with electronic stabilization is used as an inspection camera. In addition, three more cameras are mounted on the platform. This includes a pair of fixed focus auxiliary "drive cameras" mounted on the top and bottom of the chassis and a rear mounted camera with an infrared illuminator. Power is supplied by four nickel metal hydride rechargeable batteries with a run time of two hours.

All communications, including data, video, and audio, are handled through a single wireless Ethernet link. A 500mW bi-directional amplifier with a small 3dB patch antenna is used on the OCU side of the link. A 2-watt bi-directional amplifier with a 5dB omni-direction antenna mounted to the robot chassis is used on the robot side of the link. This enables the robot to be easily controlled to 300m line-of-sight.[ii]

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Figure 1. Front and side view of the URBOT

Figure 2. URBOT family

1.1 Lessons learned

Many of the designs currently used on the URBOT came from invaluable feedback from the soldiers of the 41st Engineer Battalion, 10th Mountain Division, and 577th Engineer Battalion. The original design called for a more autonomous operation system. At the Army's request, autonomous functionality was dropped in favor of a purely teleoperated system. During a tunnel reconnaissance mission, the robot needs to move slowly and stop often, allowing the operator sufficient time to closely examine the video for anything of tactical significance. A purely teleoperated system gives the user direct control over every aspect of the system.

As a result of the Army's feedback, a number of changes were also made to the robot's assemblies, control system, and video. Many of these changes fit perfectly with the SWAT's missions and tactics. The first-generation Operator Control Unit (OCU) with capacitive touch pad control unit and heads-up-display (HUD) was the first to be influenced by soldier feedback. The original touch pad was too susceptible to erroneous input by accidentally touching the wrong key. This was especially true when a soldier was trying to operate the robot while wearing bulky gloves of a chemical suit. A second-generation push button control pendant was designed to replace the capacitive touch pad.

The ultimate success or failure of a robotic scout depends on the operator's ability to reliably assess video. Because of the need to receive and display high quality video, a number of video display configurations were evaluated. The first option involved a HUD worn on the head and viewed with the left eye. The video quality of this HUD was undermined by sun glare when the operator was outdoors. A 2.5-inch LCD color video display was an alternative to the HUD, but it had its own set of negative feedback. Although it proved to be bright enough even in direct sunlight, the small screen made it difficult for a second soldier to monitor the video at the same time. The final display approved by the soldier was a five-inch active matrix LCD panel, big enough to be seen by two soldiers and bright enough to be viewed in direct light.

Additional driving cameras were also added to provide a better perspective while moving. The rear camera was added to allow the robot to back out of a tunnel if it could not turn around. The original batteries and chargers have been replaced with military batteries, to be compatible with currently used battery-powered systems such as radios.[iii]

2. CCAT

The CCAT is a US Department of Defense (DoD) funded commercialization program that utilizes the successful enterprise organizations of San Diego universities and industry. The program objective is to fast-track the commercialization of selected DoD, industry, and university technologies using these resources. The CCAT will increase the availability and applicability of commercial technologies to the needs of the US Department of Defense by promoting the efficient identification, management, development and commercialization of marketable research and technologies from academia, industry, and government.

The goal of the CCAT is to develop ventures for technologies that are dual-use, meaning they meet BOTH a commercial and a DoD need. Thus, the program is more closely tied to increasing the selection for and applicability of products to the unique needs of the Department of Defenses Acquisition community. The products should be less costly to the DoD due to the DoD's research and development investment and the commercial sector's production capabilities.

CCAT is a collaborative public-private partnership that includes four key players. Representing academia are the San Diego State University (SDSU) College of Business Administration, Entrepreneurial Management Center (EMC), ranked among the top twenty-five business schools for entrepreneurship, and The Jacobs School of Engineering, at the University of California San Diego (UCSD), a top-ten engineering school. ORINCON Corporation International, an established and highly successful defense and commercial contractor, adds the key industry perspective to the CCAT, while SPAWAR Systems Center San Diego, a premier naval laboratory, serves as the link for government generated technological concepts for evaluation for both commercialization and multi-use application.

2.1 CCAT project objectives

The primary objectives of the project were to:

- Establish the commercial benefit niche of the URBOT relative to other robotic platforms
- Identify potential market segments that can best benefit from the URBOT's unique capabilities
- Ascertain the highest potential market segment for the URBOT from a set of potential market segments
- Evaluate the demand for the URBOT in the highest potential market segment

3 IDENTIFICATION AND EVALUATION OF MARKET SEGMENTS

A variety of robotics platforms are used in a number of industries for different purposes. Most of the robots that are in current production fulfill one basic function for the user: they go places that humans cannot or will not go, and do tasks that humans cannot or will not complete.

There are a vast amount of unmanned ground robots in production today. Some platforms are designed to be adept at transporting items and have robust towing capabilities; others are specifically designed to work well in confined environments. Some platforms specialize in scouting and surveillance activities, while others offer the ability to traverse arduous terrain in a variety of environmental circumstances. The ability of a specific platform to be man portable is also a major distinction between different robot formats.

Some platforms are equipped with substantial motors and use heavy steel frames that enable them to carry payloads in excess of 1000 lbs. These robots are often described as material handling robots and posses the capability to move very large items that humans alone cannot move. Many of these units are often equipped with heavy duty track and/or wheel systems that allow them the ability to traverse all types of terrain including mud, snow, and water. Often they are also outfitted with maneuverable arms. While rather fast and strong, most robots that fall in this category are not very agile and often require wide-open spaces to operate properly. These robots are also generally very heavy and require multiple individuals and large trucks in order to transport them.

There are a significant number of robots that are designed to work well in confined areas, such as pipes. These robots generally have a near zero turning radius and can fit through very small openings. However, their ability to work well in confined areas does come with its drawbacks. Many of the platforms designed to work well in confined areas, lack the ability to traverse interior stairwells with much proficiency. This trait can render a robot that specializes in confined pipes useless, due to the fact that many urban robot situations occur where the goal of a particular mission requires that the robot move to and from different floors in a building.

Many robots possess the ability to act as a scout and survey locations that may be unsafe for humans. Robots in this category are generally equipped with video cameras that link back to handheld display units. Some have audio communication capabilities as well. These robots offer operators much in the way of surveillance.

The URBOT is competing with other robotics platforms that are designed to perform video surveillance duties, traverse varied terrain, and operate in confined spaces. This information immediately narrows the scope of potential markets to

serve and gives a smaller pool of robotics platforms to compare the URBOT to. Given the URBOT's strengths, features, size, weight and task applicability, a set of more focused market segments can be identified and critically examined for market attractiveness. These segments include:

3.1 Nuclear waste disposal site inspection

Most Transuranic Waste (TRU) and Low-Level Waste (LLW) are stored in above-ground drums or other containers stacked in rows in warehouses at Department of Energy (DOE) facilities. EPA and DOE requirements mandate regular inspection of the storage areas and require significant manpower resources. In addition, radiation levels external to the storage containers may present a hazard in that inspection personnel could be exposed to significant radiation levels during the inspection process.

An enhanced commercial mobile vehicle is capable of meeting many of the demands of the missions of environmental compliance at DOE sites. This mobile robot, *ARIES* (A Robotic Inspection Experimental System), is designed to navigate rows of drums while performing automated visual inspection with cameras positioned to inspect the drums.

To compete effectively in this market base the URBOT would have to be modified to withstand chronic, low-level radiation exposure. The URBOT would also need to inspect multi-levels of waste drums. It is unclear how quickly and what effect such modification would have on the URBOT's availability and resulting price.

3.2 Civil engineering maintenance: Bridge inspection

Federal law mandates that each bridge, spanning more than 20 feet in America, be inspected once every two years. Ideally we would have an inspector, sitting in a truck on the bridge controlling a robot that can "view" the entire bridge through a sensor suite deployed at the end of the robot. A bridge inspection robotic system would reduce the cost of inspection, increase the safety factor, provide better views of the bridge, improve the quality of information, and as an added benefit, decrease traffic delays that are a result of such an operation.

Conventional mobile robots and robot arms cannot adequately perform bridge inspection because they lack the flexibility to reach all locations in highly convoluted structures which most bridges offer. The URBOT also lacks the mobility to adequately inspect a bridge.

3.3 Civil engineering maintenance & Urban Search and Rescue (USAR): Building Inspection

A good job opportunity for a scout and surveillance robot would be in partially collapsed or damaged buildings, where there is still some structure remaining and you need to get in real fast to determine whether the building is stable. Robots can easily enter these damaged buildings, move in the rough terrain, cross obstacles, and move in narrow spaces that would be difficult or dangerous to be accessed by human inspectors.

Building inspection robots can often do an inspection of a structure faster than human inspectors can, and do so without risk to human life. The URBOT is well suited for this task and has been used in this capability at the World Trade Center (WTC) disaster after 9/11.

3.4 Urban Search and Rescue (USAR): Victim Recovery

Robots could be used to search collapsed buildings and find victims. If victims are found, robots could be used to deliver payloads such as medicine, food, and water to victims trapped under debris. Robots could also have the potential to free trapped victims and move them to safety.[iv]

The environment found under a collapsed building is utterly unstructured and next to impossible for a robot to traverse. While unable to traverse most ruble in a collapsed building, robots could be lowered into caverns and tunnels that are unstable to be safely explored by a rescue team. No robots are being produced specifically for urban search and rescue. Military scout and surveillance robot have been tried in this role, with unsatisfactory results. USAR teams are also reluctant to try the new robot technology, relying on old and proven methods of victim recovery.

3.5 Civil engineering maintenance: Pipe inspection

Blockages in water, sewer, and gas pipes can create big problems and be very costly. Pipe inspection robots need to go through elbows, T-joints, and travel long distances in horizontal pipelines. Some inspections will require in-pipe inspection robots that can go through vertical pipelines.

The URBOT's performance pipe inspection applications are questioned based upon its size. Clearly in looking at the competing products attempting to perform these tasks, robot size is more highly valued that say, remote operation.

3.6 Industrial maintenance: Duct cleaning

Air duct cleaning is an important industrial maintenance that ensures the cleanliness and quality of air supplies to large, commercial buildings. Accumulated dust creates a basis for bacteria and fungi. These might, within time, free themselves from ducts and be transported into the ventilated rooms causing illness for the occupants.

Despite the large number of robots available for pipe inspection, there are fewer systems on the market for air duct inspection. Air ducts have characteristics very different from underground pipes: air ducts have many curves, have a strong air flow, normally do not have water in them and can have square or circular sections. To inspect this type of ducts there is a need for small and agile systems.

The URBOT's remote control capability would make it an excellent competitor to this existing platform. Yet it is evident that the existing URBOT must be outfitted with a specialized sweeping apparatus before is can be applied to this market. The size of the URBOT is once again an issue in air duct inspection and cleaning.

3.7 Shipping & Maritime: Hull inspection

The importance of maintaining hull and lining integrity of oil tankers is clear. Residual oil, small space and overall toxic environment make remote visual inspection very attractive.

The URBOT would seem to lack the submergibility that this market needs although it does have a waterproof housing. Its robust shell may or may not be suited to this task without modification to withstand oil, sludge and even gasoline.

3.8 Mining Industry: Mine mapping

The mining industry is a large market and is in need of the ability to safely map newly opened mines and caves. There is also a need to get into and explore sealed mines. Sealed mines frequently have areas of collapse or flooding making them unsafe for human exploration. Two recent coal mine accidents in Appalachia have led to calls for the establishment of national standards for documentation of underground mines and for a reassessment of the state of technologies, such as remote sensing and mapping, available for the task. Robots could improve mine mapping, particularly of abandoned and sealed works, to help prevent future accidents. There is a real need for a renewed effort to ensure the accuracy of mine documentation.

The URBOT may have a home in the mining industry with only the addition of mapping hardware.

3.9 Construction industry: Caisson remote visual inspection

Caissons are the "footings" upon which bridges are built. Small projects normally require no inspection as the footings are laid one at a time. Yet large, civil engineering projects for large bridges would require this capability to ensure the stability and quality of each caisson. Currently, alternate methods of inspection are being used such as cameras attached to booms.

3.10 Law Enforcement

A variety of possibilities exist for robotic applications within law enforcement and indeed the competitive landscape is filled with players attempting to gain access to this lucrative market. Within law enforcement, SWAT units are already gaining experience with using robotics platforms to perform their dangerous task.

The overwhelming majority of SWAT/Special Operations teams throughout the US use a Remotec/Northrop Grumman Andros robot. The cost, speed, and reliability of the Andros does not meet the thresholds identified in the NIJ report[v], and direct interviewees stated similar dissatisfaction.

4 POTENTIAL SEGMENT SUMMARY

The existence of specialized, superior technologies already serving market segments and the necessity of major modifications to the base URBOT were the primary determinants of market attractiveness and potential. Because the existing URBOT platform is best suited to applications where its good communications and surveillance capabilities can be used, market segments that need major modifications to the base unit were given less priority than those markets that could use the URBOT "as-is". Below is a consolidated chart representing the identified potential markets and brief comments about their application needs and initial attractiveness.

	Segment	Task	Pros	Cons	Attractiveness (High, Medium, Low)
1	Nuclear waste: disposal site inspection.	Can be lowered into space between walls of waste tanks to inspect for weld faults.	Remote inspection, only safe method of accomplishing task due to radiation.	Existing technologies address need.	Low
2	Civil engineering: bridge maintenance.	Remotely inspect heavily trafficked bridges for structural integrity.	Remote inspection, only safe method of accomplishing task.	URBOT is not configured for climbing under bridges.	Low
3	Civil engineering: pipe maintenance.	Natural gas line, water, sewer inspection.	Large market potential.	Size is a large limitation. Existing technologies address need.	Low
4	Civil engineering & Urban search and Rescue: building inspection.	Inspect/survey damaged buildings that are unsafe to enter.	Remote inspection, only safe method of accomplishing task on damaged structures.	Reluctant users in USAR. Robots virtually unproven in this field.	Medium
5	Urban Search and Rescue: victim recovery	Can be lowered into collapsed rubble to search for survivors.	Remote inspection of collapsed building and victim search.	Size is a large limitation in this unstructured environment. Reluctant users.	Low
6	Industrial maintenance	Inspect/ Sweep out building air duct lines.	Large market potential. Required adaptations simple.	Size may be a limitation. Smaller technologies exist.	Low
7	Shipping / maritime	Remote visual inspection of hull interiors.	Chemical / moisture resistance a plus. Large market potential.	Market need unclear. More research necessary.	Low
8	Mining industry	Remote visual inspection of unstable shafts/ newly opened areas and sealed mines.	Durable architecture attractive in such an environment.	Vertical drops and flooded areas may cause problems.	Medium
9	Construction industry	Caisson remote visual inspection.	Durable and remote inspection capability desirable.	Market need unclear. Size and mobility may be a limitation.	Low
10	Law Enforcement	Remote surveillance robot usage scenario.	Some SWAT units already using robotic technologies.	Purchase price can be a critical concern.	High

4.1 Fit of the URBOT: Evaluate and Eliminate

The competitive landscape and a clear understanding of the URBOT's capabilities and limitations help the evaluation and elimination process of examining the list of potential market segments and picking the best.

		Can the URBOT perform the task? Yes	No
Are major modifications necessary?	Yes	Yes, but with major modification	No, but could with major modification
	No	Yes, with no modification necessary	No, not at all

Our goal is to find the market segments that fall into the lower left quadrant of this matrix. There, the market(s) can derive immediate use and be most interested in the present generation of the URBOT. Missing from this categorization tool is the possibility of yes, the URBOT indeed *can* do the task but an existing, more specialized robot is adequately serving that particular market.

Prioritization of the generated list of potential markets occurred with this matrix and the question of existing technologies in mind.

		Can the URBOT perform the task? Yes	No
Are major modifications necessary?	Yes	Nuclear Waste Disposal Pipe Inspection Mining Industry Air Duct Cleaning	Bridge Inspection Construction Industry Shipping / Maritime Victim Recovery
	No	Building Inspection Law Enforcement	

Here research and competitive intelligence allows the categorization of the ten potential market segments. The majority of markets fall into the top half of the box wherein the URBOT can and is suited to perform the remote inspection task necessary, but would require major modifications or is totally unsuited for the task.

The remote inspection of buildings and the law enforcement market segment are the only two markets that could use the URBOT in its present form. Law enforcement and building inspection (civil engineering and USAR) would seem to be the best fit for the URBOT based on its ability to use the URBOT "as-is" and the fact that the URBOT's features and usage scenarios lend themselves well to crisis and crisis management situations. The need for building inspection in the civil engineering market remains unclear and requires more research. USAR teams are reluctant to use the new robotic technology in a crisis situation. This was proven at the WTC disaster, where USAR teams waited days to try the new technology. This reluctance to try and use robots eliminated the USAR market from the survey.

5. Law Enforcement Need

Primary CCAT research focused on interviews with personnel closely linked to the URBOT's benefit niche, such as law enforcement personnel with experience operating robots in the field.

5.1 Demand estimate for the URBOT in law enforcement

Examination of U.S law enforcement structure, and a prioritization of those segments based on usage, need, and accessibility should provide a reasonable demand estimate for the URBOT within law enforcement. This demand estimation process will flow from a very broad overview of law enforcement in the U.S. through successively tighter restrictions based on use patterns and likelihood of need for the URBOT technology. It will ultimately identify the market within law enforcement with the highest potential.

There are around 18,760 separate police agencies in the U.S. with approximately 940,275 employees and a combined annual budget of about $51 billion (year 2000). Police agencies are found at all three levels of government: federal, state, and local. Local police agencies can be further separated into two levels: municipal and county.

Overall, there are roughly 60 different federal police agencies with over 88,000 officers. The federal agencies include the DEA, FBI, U.S. Marshals and ATF. There are over 49 different state agencies, including Highway Patrol and State Police, that make up another 300,00 officers. Local police in over 15,000 municipal police departments are an additional 400,000 officers. Sheriff, special jurisdiction, and Texas constables make up another 100,000 officers.

5.2 Law Enforcement Segments Discussion

External market factors and acceptance of robotics technologies to perform in certain situations weigh heavily in the decision to target a particular law enforcement segment.

- All levels of law enforcement in the U.S. have an elite, specially trained SWAT team
- The primary "scout" function of robotics in law enforcement is well suited to the most common SWAT call-out: to handle a barricaded suspect
- Mesa Associates, maker of the *Matilda*, have sold exclusively to SWAT
- Agencies (ATF, DEA, etc.) typically look to SWAT to handle special, especially hazardous situations.
- SWAT agencies nationwide are already utilizing robotics technologies and readily accept and are willing to evaluate emerging solutions

Agency	Use Robotics?	Current Need?	Budgeting for Robotics?	Rank (out of 4 stars)
FBI	Yes, but through SWAT	No	No	*
DEA	No	No	No	*
INS	No	No	No	*
U.S. Marshals	No	No	No	*
ATF	No	No	No	*
S.W.A.T	Yes	Yes	Yes, some	****

5.3 Existing demand from SWAT agencies

The most attractive "beachhead" market segment for the URBOT is the city/county SWAT teams of sufficiently large and technology-friendly cities. The performance profile and applicability of the URBOT platform has the strongest and most compelling need within this segment. Based on primary data regarding usage patterns of SWAT as well as other law enforcement agencies and the clear message from SWAT agents and their leadership for effective robotics technologies makes the decision for targeting SWAT teams as a "beachhead" market justified. The assumption was made that SWAT agencies servicing the largest metropolitan areas would be of sufficient size and have adequate monetary resources to buy into a new robotics technology like the URBOT. That is, we felt the initial adopters of the URBOT will come from larger, financially capable, and more technology-friendly agencies. We will concentrate on establishing a "beachhead" market from among the largest metropolitan areas in the U.S. with over 2 million inhabitants.

5.4 Adoption Curve and SWAT Team Technology Diffusion Patterns

It bears mentioning here briefly the nature of technology adoption with respect to law enforcement and SWAT agencies in particular. This is seen in the adoption curve (Figure 3).

Innovators and visionaries are always the first to adopt a new technology because they see a potential energy, cost, or life saving advantage that a new technology can offer. They are characterized as being very open to technology and changing the way they perform their jobs. They are, in fact, looking to revolutionize the way operations have been previously performed and are willing to pay a little bit extra in hopes of that breakthrough.

The early majority is looking for the "whole product". They want to hear that a new technology, like the URBOT has been tested and has good word-of-mouth recommendation before they are willing to buy into its use. They are also very

interested in the fact that there is direct competition to a new technology because competition means to them that the target technology is lucrative and warrants business.

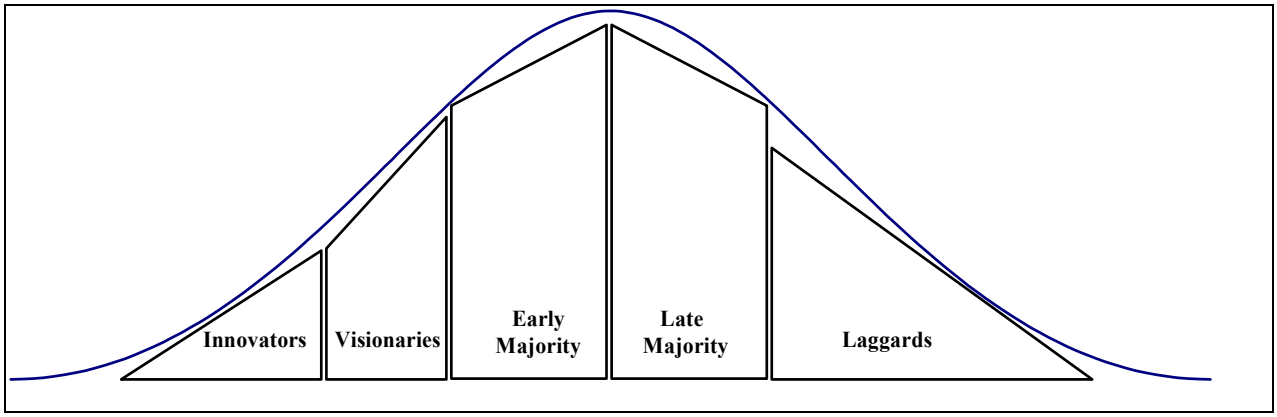

Figure 3. Adoption Curve

Early majority SWAT teams in smaller cities are not relegated to waiting on the innovators and visionaries to give the technologies a stamp of approval before deciding to try it out. SWAT teams that have robots like the *Andros* and *Matilda* regularly lend out their robotics to smaller SWAT units in surrounding counties and states. This is important because we see that smaller SWAT units around the country look to the innovator/visionary SWAT units to test out new robotics platforms and subsequently lend them a robot and a trained officer/agent to teach the local team to use the robot. If the URBOT can establish a strong presence and begin generating a good reputation with these lead users, the technology can diffuse more rapidly down to the smaller SWAT agencies around the country by means of this established robotics lend-and-teach practice.

6. FEEDBACK RELATED TO SEGMENTS: GENERAL AND SWAT SPECIFIC

A thorough search of industry websites, technology and law enforcement databases, and published articles was completed. A great source of information uncovered in this search was a survey conducted by the National Institute of Justice (NIJ).

6.1 General Feedback:

In April 2000, the NIJ conducted a study and released a report on robot technology within law enforcement. The primary goal of the study was to define and document civilian bomb technician and law enforcement user needs with respect to robot vehicles. In all, data was collected from over 125 people from the bomb disposal and law enforcement robot community. Twenty-eight states and 40 cities, ranging in population from 20,000 to 7,000,000 were represented by this market survey. The NIJ Final Report on Law Enforcement Robot Technology Assessment results follow:

It was found that law enforcement robots require nine key attributes (in no particular order):

1. Adequate speed
2. The ability to fully complete a mission
3. Minimal weight for the mobile portion of the robot system
4. Low purchase price (cost)
5. The ability to operate, when needed, for training or actual missions (minimal down time)
6. Minimal maintenance requirements
7. Low annual maintenance cost
8. Adequate manipulator lift capability
9. Adequate operating range

6.2 Final Robot Objective and Threshold Values:

Attributes	Objective	Threshold
Cost ($)	20K	30K
Manipulator Lift Capacity (lb.)	45	35
Manipulator Lift Range (Inches)	18	-
Operating Range (Yards)	450	300
Training/Utilization Requirements (Hrs/Month)	13	8
Mission Duration (Hrs)	4.5	2
Maintenance Requirements (Hrs/Month)	0.5	2
Annual Maintenance Cost ($/Year)	300	500
Speed (MPH)	3	1.5
Weight (lb.)*	95	130

* Interviews with SWAT members required one man lift and carry, ~ 30 to 35 lbs.

6.3 How URBOT Compares:

Attribute	URBOT	Meet Objective	Meet Threshold
Cost	currently around $70K	no	no
Manipulator lift capacity	NA	-	-
Range	100M below ground	no	no
	250M above ground	no	yes
Training	minimal	yes	yes
Mission Duration	2-3 hours	no	yes
Maintenance time	minimal	yes	yes
Maintenance cost	$1500 just for batteries	no	no
Speed	1.7 MPH	no	yes
Weight	65 lbs	yes	yes

6.4 Requirements

After reviewing the study results, the NIJ put together design guidelines for any future law enforcement robots.

Prioritized requirements:

- Cost – target price should be $30,000, including control unit, batteries, and all necessary parts
- Manipulator lift capacity – arm should reach 18” out and lift 35lbs
- Range – minimum distance of 300 yards
- Utilization – robot should be able to operate at least 8 hours/month
- Duration – robot should operate for a least 2 hours
- Maintenance time – not to exceed two hour/month
- Maintenance cost – not to exeed $500/year
- Speed – at least 1.5 mph on cement
- Weight – 130 pounds or less

Performance requirements:

- Operational in temperatures from –40 to 120 degrees F
- Water-resistant
- Size – no taller than 3 feet, able to fit down isle ways and narrow passages
- Audio – robot should provide two way communication
- Durability – robot should withstand rough handling, shock, and vibration
- Delivery – robot should be easily loaded and unloaded from transport vehicle

- Mobility – all terrains with out damage to tracks or wheels. Should climb stairs
- Handles – should have points for use to pick up and carry/move robot

Camera requirements:
- High quality color video
- 360 degrees on vision
- Drive, rear, and manipulator view

Other attachments:
- Modular construction – add or remove different components depending on situation
- HAZMAT detector – explosive, chemical, biological, x-ray, and nuclear detection equipment
- Manipulator-mounted camera
- Disruptor – multiple ammunition capable, water round blanks, clay rounds, and slugs

URBOT currently satisfies many of these requirements. It currently does not have a manipulator/lift arm, but that may be a future possibility.

7. SWAT FEEDBACK

Direct structured interviews with county SWAT/Special Operations teams were conducted in the use of robotics in special operations. Results of the interviews include the following essential features and URBOT feedback. At a minimum, the tactical robotics platform needs to:

7.1 Be multi-functional

The robotic platform needs to provide the ability to perform more than one function. While the primary purpose is to remotely deliver a means to communicate with barricaded suspects, it should also be able to fulfill other related functions. This includes such missions like remote surveillance and listening capabilities. The URBOT's video system was a big success with SWAT. They liked the multiple cameras, views and functions that the URBOT has. The ability for the URBOT to listen was also welcomed, but two-way communications would be a required feature.

Some features, although not absolutely essential to the basic mission of a tactical robotics platform, are certainly critical in providing additional capabilities to SWAT teams attempting to achieve successful resolutions in certain high-risk tactical situations. One of these features is the delivery of chemical agents. This feature would be very useful in situations where conventional methods of delivery become difficult or dangerous. An articulating arm capable of picking up or moving small objects would also be useful for retrieving or placing items as well as twisting door handles, moving doors and windows and so forth.

7.2 Have a user-friendly interface

The addition of robotics will undoubtedly provide new and unique advantages but will require additional training to fully exploit the capabilities. Consequently, a friendly, intuitive interface which requires a minimum of training to master is critical. While the URBOT's backpack OCU with 5-inch hand held display and driving pendent was designed with the Army Engineers in mind (with a lot of soldier feedback), the OCU was not well suited for SWAT operations.

The limited space on the driving pendant limits the number of buttons that can be accommodated. Due to this limitation, a menu-driven approach was taken. The menu is used to cycle through the various functions such as headlight intensity, camera selection, zoom, and focus. This approach was not well received by SWAT, because the buttons and menus made robot operation a little tricky. This was especially true when scrolling through the menu functions and accidentally choosing the wrong function. They would like to see a one-button/switch/knob per function, in addition to a larger display, such as a 10.4-inch Active Matrix Color LCD Panel.

Another issue is the weight of the 20-pound URBOT OCU. SWAT personnel now carry enough equipment on their person and do not want to carry any more equipment. Any SWAT operations requiring a tactical mobile robot would not

call for a mobile/tactical OCU. A SWAT robotic operator would be safely stationed in or behind a police cruiser controlling the robot.

7.3 Have a versatile control system

While there are advantages to both a remote radio controlled and a "tethered" control system, they each have their own disadvantages as well. Where a radio controlled system is preferred, if the batteries die or the robotics platform becomes stuck it may be impossible to retrieve it. A tethered platform may allow the robot to be pulled back and restarted. Consequently, a "dual control" system, one that does not rely solely on one type of control system or the other is preferred.

The URBOT is a radio controlled platform because its military users frowned on the idea of tethered" control. However the system could be easily configured to run in a tethered mode if there was enough interest from other users.

7.4 Have a versatile power source

Crime scenes that will require the use of robotics are varied and unpredictable. Power sources must be able to adapt to the conditions present at the time and place the robotic platform is employed. This may require 110-volt AC "house current" or 12-Volt DC batteries from police vehicles, but may also require the use of other types of power.

The URBOT's batteries can be charged from a 110 AC or from a 12, 24 or 36Volt DC automotive source. The drawback to the URBOT's power source is that they are nickel metal hydride military batteries. They will give the URBOT a run time of two hours, but at a price. These batteries are expensive and can only be charged twenty times. This is a costly maintenance requirement that SWAT would not want when their goal is to keep maintenance cost down to $500.00 a year. Battery replacement would cost SWAT at least $1500 a year, assuming just one set of batteries in stock and no spares.

7.5 Be extremely portable

The ability to get a robot into a favorable position for employment may require that it be carried in elevators, across roofs, through bushes and so forth. Consequently, a small, lightweight robotic platform is desirable. To the maximum extent possible, the robotics platform should be able to be carried in a backpack or other similar method and deployed near the place it is actually needed.

The URBOT fails in the quick deployment category. At 65 pounds and dimensions of 34 by 21-inches, the URBOT is a bit bulky and very difficult for one person to carry. Such size and weight dictates that two SWAT members are needed to deploy the robot if it is to be thrown into a window or over a wall. The SWAT team is unhappy about this because this means two members of the team have to be out in the open and in harms way.

Further, it should be rugged enough to withstand rough handling and dropping as well as the effects of extreme heat, moderate cold and inclement weather. Being designed for military operations, the URBOT has proven itself to be a very rugged system. It has handled being driven in extreme cold (fort Drum, NY) and heat (Afghanistan) by soldiers. It has also been accidentally dropped-tested a number of times, including a 13 foot fall off of a second story balcony.

7.6 Traverse common obstacles

Much of the terrain, both indoor and outdoor, in which a robotic platform may prove useful in SWAT operations is rugged, constricted and difficult to traverse. Not every home that SWAT enters is a model for "Better Homes and Gardens". One of the biggest threats to robot mobility in the urban home environment is the home that has not been remolded since the 70s (Figure 4). Tacky orange shag carpet, with some dirty clothing thrown on top is a real showstopper for robots. The carpet binds the robot treads making it hard to turn and the clothing will get caught up in the tread sprockets bringing the system to a halt. How many tactical small robots have been actually tested in this environment?

Tight winding staircases are also a problem for many tactical robotic systems. Many systems will get stuck in them or become inverted. For this reason, the robot needs to keep driving, even if it flips over. The URBOT is fully invertible and can even continue a mission upside-down. This is a function that SWAT was extremely impressed with. Both of

the current systems in use by the Los Angles SWAT team did not perform well in staircases. One system is a little too large to handle a winding staircase in the middle; the other unit has to be driven down the stairs backwards or it would turn turtle and require rescuing.

Figure4. That 70's Home: a 70's home flashback, with nice orange shag carpeting. Throw some clothing on top and you have a major obstacle to robot mobility.

7.7 Be adaptable to additional functions at a crime scene

The expense and difficulties in purchasing, developing and employing a robotics platform are considerable. Consequently, while delivering a telephone is an essential function for negotiations, after the telephone is delivered the robotic platform should be able to return to the point of departure and be reconfigured to provide additional functions such as surveillance, remote listening and so forth. In order to achieve this, the platform must be able to easily and quickly adapt to other functions. SWAT also recognizes that one robot may not be able to do everything and there may be a need for two systems.

SWAT realizes that a small lightweight robot may be perfect to throw through a window and explore the first floor of a multi-story building, but it will have other shortcomings. A small system will have limited run time, will not be able to climb stairs and will be too small to carry a manipulator. For those jobs, a second, larger robot could be sent in after the first area has been explored by the smaller system.

While the URBOT is not equipped with a manipulating arm, it could be easily modified to carry one. Both hardware and software of the system was easily modified to carry a Nuclear and Chemical Agent Payload Module upon the military's request (Figure 5).

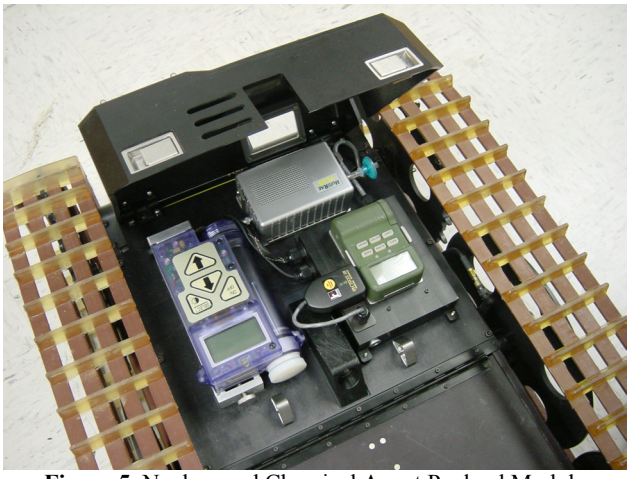

Figure 5. Nuclear and Chemical Agent Payload Module

7.8 Have passive communication

A useful SWAT robotics system needs to have the capability for passive two-way conversation/communication. Negotiators/tactical personnel must have the ability to converse with - and listen to - suspects or victims without having to rely on actual physical participation (i.e., picking up a phone, pushing a button, etc.) from the suspect or victim.

The URBOT is currently equipped with one-way communications from the robot to the operator. Two-way communications is another feature that can be easily provided in the system when required.

7.9 Be low cost

Expense becomes an important issue with the very real danger that a robotic platform can be damaged during a deployment The fact that the state of the art in robotics is rapidly advancing also drives cost. A low cost robotic platform would allow damaged or destroyed devices to be quickly replaced as well as upgraded when and if a better model becomes available. Price can be a huge concern. Buyers increasingly balk once prices start going over $35-$40K. It is difficult to push for the purchase of a robot (or any item) when it costs more than a squad car (~$30K).

While cost is an issue for the bookkeepers and purchasers, it is not a real issue for SWAT members. It the robot takes a bullet, it has done its job. You lose a robot and some money, but you haven't lost a police officer.

7.10 Have good video capabilities

A video camera capable of sending signals back to remote monitors would be especially useful. The camera should be able to "see in the dark," have a large field of view and/or be traversable, be able to zoom in on objects for greater clarity and not interfere with other functions. In this manner, the robotic platform could perform the role of an observation post without the risk of human sentries. The ability to record the video signal would be useful for debriefings, training and courtroom presentations. The ability for multiple observers to simultaneously obtain video and/or pictures from the robotics platform would provide an increased situational awareness for intelligence and decision making purposes.

Many of these functions are incorporated into the URBOT. After a number of robotic demonstrations given at the SPAWAR lab to visitors, it was found that a central robotic control center would be useful. Video from up to nine robots, including the URBOT, can be displayed at once in the Robotics Operation Control Center (ROCC). Video is easily captured with the use of a small digital camera placed in the OCU for future viewing.

Figure 6. Robotics Operation Control Center

8. SUMMARY

While the robotics industry offers a wide range of platforms, each with its own specialization, the industry lacks a multifunctional robot that is durable, works well in confined areas, can act as a proficient surveillance tool, is man portable, and can be purchased for less than $80,000. Through the CCAT program, it is hoped that we will be able to leverage government technology to the maximum extent and transfer this technology to good business practice with industry. With the help of industry, a more responsive, deployable, agile, versatile, survivable, and sustainable system can be produced. Through the teaming of government and industry, we hope a robotic platform suitable for SWAT operations can be produced for $30K, half of the current cost of an URBOT.

Any robotic platform that will be used by SWAT, at a minimum, requires these basic functions and capabilities:

1) A recognized need for a simpler and more reliable surveillance robot that would be used to send into a house before a raid, clear rooms, and identify threats
2) A need for man-portable systems
3) An arm or disrupter is unnecessary but a nice feature, with bomb units requiring the additional need for such attachments
4) The most important feature of the system is good cameras
5) Good at climbing stairs and being invertible
6) Listening and two-way communications for barricaded platforms
7) User-friendly interface such as a pelican brief

The URBOT is not a “whole product”. The stand-alone URBOT is a remote surveillance platform that may or may not be intuitively useful to SWAT agencies. That is, trying to sell *just* the URBOT to SWAT teams that have little to no experience with robotics will be a difficult task. A solution is to bundle training with the URBOT to mitigate any Fear, Uncertainty, and Doubt (FUD) Factors in the minds of potential buyers. This might be in the form of CD-ROMs, videos and flip-book style manuals that offer suggested tactics and situational tips for the applicability of the URBOT.

An additional effort to overcome FUD is to get the URBOT and its associated training to the various national SWAT training sites. Here, SWAT teams from across the country can get exposure to the URBOT and learn about its uses and potentially generate interest and sales.

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